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Testing the Lateral Deformation Gauge on Large Diameter Cemented Rockfill Cylinders During Uniaxial Compressive Testing

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MRL 92-011 (TR) March, 1992

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Introduction

Due to the large scale samples that are tested by CANMET's Sudbury laboratory, it was necessary to acquire some sort of device for measuring lateral deformation in these cylinders during uniaxial compression tests. In February, 1992, a lateral deformation gauge was designed and built (Millette, 1992). To determine if this gauge would be suitable for testing such cylinders, tests were carried out on three 457mm diameter cemented rockfill cylinders.

Testing was carried out at the Elliot Lake Laboratory in late February, 1992 by personnel from the Sudbury Laboratory.

Cemented Rockfill Cylinders

It was decided to mix three cemented rockfill cylinders to test the gauges. Two of these cylinders contained 8% binder while the third was a 6% mix. The binder consisted of a 50/50 mix of type 10 normal Portland cement and type C, Great Lakes flyash. The aggregate was made up primarily of 70% minus 2" rockfill material and 30% mill tailings. It was decided that the finer material and the higher (8%) binder content would give a much smoother surface than standard rockfill cylinders.

Mixing of Test Cylinders

The test cylinders were mixed in a 0.25 m^3 concrete mixer. A predetermined amount of water was weighed and placed in the mixer and the mixer switched on. The flyash and cement were both weighed according to a percentage of the total dry aggregate weight and dumped into the mixer. This combination of water and binders yielded a slurry with a pulp density of approximately 57%.

The aggregates had been premixed in drums for another project carried out by personnel at the Elliot Lake Laboratory. This aggregate mixture was weighed and shovelled into the mixer. Once mixing was completed, the cemented rockfill material was poured into 457mm diameter by 914mm high waxed cardboard moulds (sonotubes).

The cylinders were then covered with a plastic bag to maintain humidity during curing. The cylinders were weighed and the densities calculated (Table 1). They were allowed to cure for 12 days, capped, cured for another 2 days and tested.

Capping

The cemented rockfill cylinders were capped with a mixture of normal Portland cement, plaster of Paris and water. This capping compound and procedures were used in the testing of cemented rockfill cylinders for the Macasssa Project (Annor & Millette, 1991).

Uniaxial Compressive Testing

Before testing, the moulds were stripped from the cylinders. The two cylinders with 8% binder content had few surface voids and resembled concrete cylinders (Figure 1). The one with 6% binder content had an array of surface voids much like previously tested, cemented rockfill cylinders (Annor & Millette, 1991). This would allow us to test the gauge on both types of surfaces to simulate actual conditions that normally occur in our regular testing program.

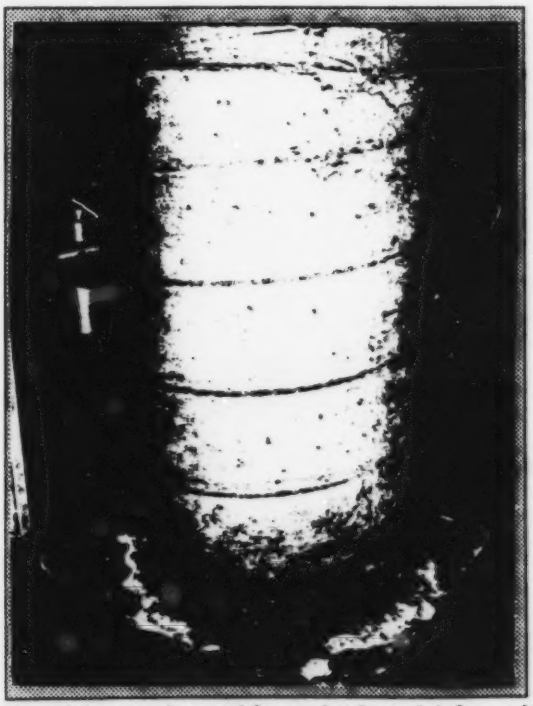


Figure 1 - One of the samples used for testing lateral deformation gauges

Compression of the cylinders was done with a Gilmore, 2,000 ton hydraulic press (Figure 2). The press was set to operate in strain control with a constant downward movement of the upper platen of 0.03mm/s. The gauges were attached to the cylinder (Figure 3), and the cylinder placed on the lower platen of the press.

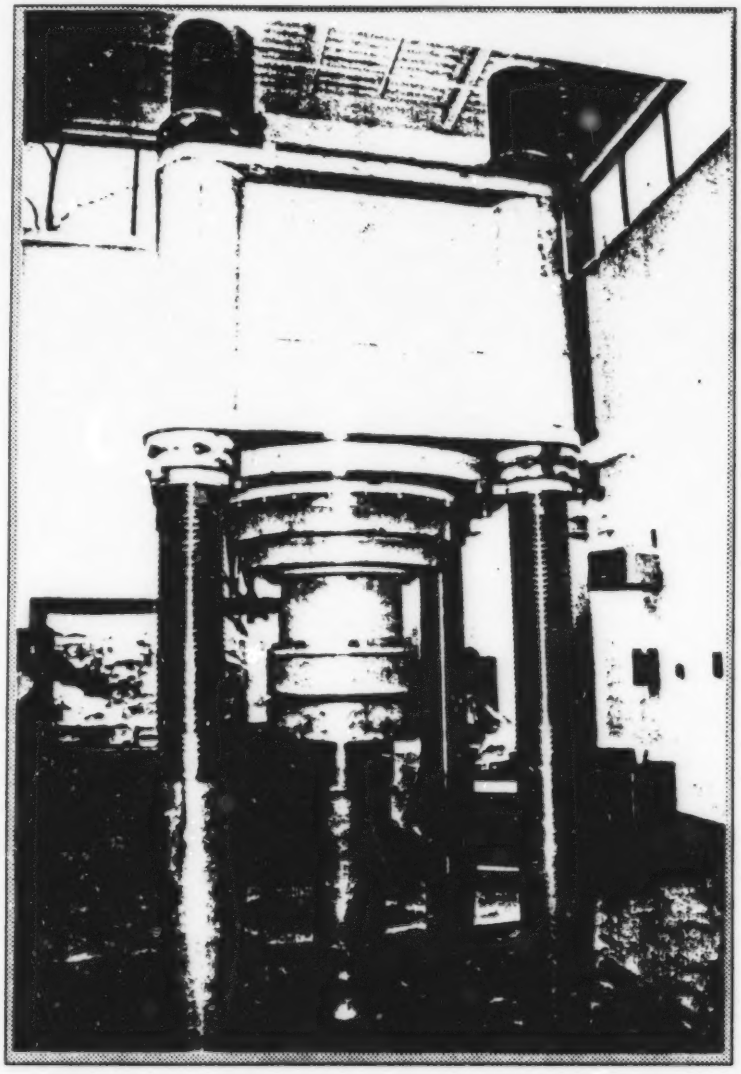


Figure 2 - Gilmore 2,000 ton hydraulic press

The gauges were then connected to a distribution box. This distribution box was attached to a 12 volt DC, regulated power supply. A Fluke model 2208A data logger was connected to the distribution box and each channel was programmed with the calibration factor for the LVDT on a particular gauge. The gauges had been calibrated during assembly (D. Millette, 1992).

The data logger was set to record load and axial deformation from the press console and lateral deformation from each of the three gauges at 5 second intervals. This data was recorded and down-loaded to a spreadsheet program for plotting to a graph. The test data and corresponding graphs are presented in Appendix A.

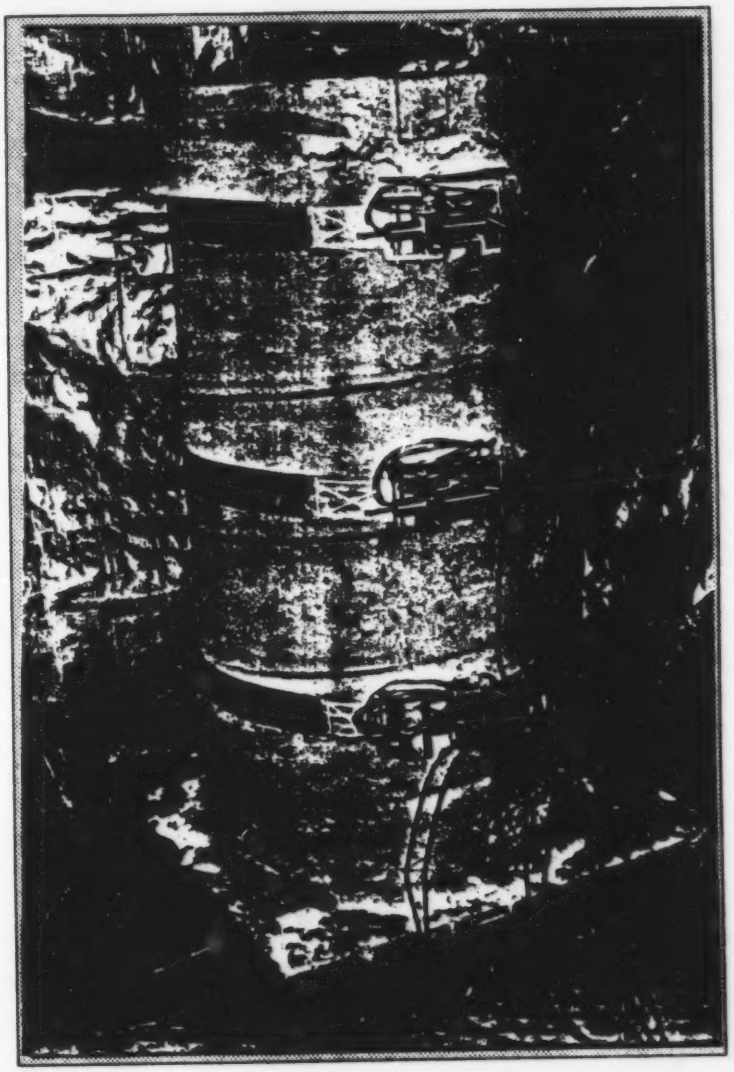


Figure 3 - Cylinder showing lateral deformation gauges attached

Table 1 - Uniaxial compression test results

	Binder Content (% by weight)	*Fill Density* (kg/m^3)	*Max. Compressive Strength* (MPa)	*Young's Modulus* (GPa)
Cylinder #1	6	2353	5.46	2.073
Cylinder #2	8	2509	8.89	1.005
Cylinder #3	8	2578	8.38	1.550

Conclusions

From the data collected by the gauges, it was possible to calculate Poisson's ratio. A summary of the data is shown in Table 2.

Table 2 - Gauge readings and lateral deformation values (in mm) at maximum load

	Gauge #1 (top)		*Gauge #2* (centre)		*Gauge #3* (bottom)	
	RADIAL	LATERAL	RADIAL	LATERAL	RADIAL	LATERAL
Cylinder #1	0.00	0.00	0.06	0.02	0.03	0.01
Cylinder #2	0.21	0.07	0.01	0.00	0.00	0.00
Cylinder #3	0.11	0.04	0.00	0.00	0.00	0.00

The gauges worked well and proved to be capable of measuring changes in diameter as little as 0.01mm. But with these gauges as well as with any strain gauges used on this size of sample, there is still an element of judgement involved. With the first test cylinder, there was lateral deformation at the centre and bottom gauges only. Cylinder 2 showed deformation at only the top and centre gauges while cylinder 3 showed movement at the top gauge only.

The sample being tested must be observed during compression to determine what is actually happening to the cylinder. In the case of cylinders 1 and 2 deformation occurred before failure. But a decision must be made on whether to average the readings from all the gauges, just the ones showing movement or simply the centre gauge. For comparison purposes, Table 3 shows the Poisson's Ratios before failure by different combinations of the above methods.

Table 3 - Comparisons of Poisson's Ratios

	Gauge #1	*Gauge #2*	*Gauge #3*	*Average All Gauges*
Cylinder #1	0.00	0.35	0.04	0.13
Cylinder #2	0.14	0.07	0.00	0.07
Cylinder #3	0.34	0.00	0.00	0.11

Poisson's Ratio is the modulus of the lateral strain over the axial strain. Table 2 shows the Poisson's Ratio values for each gauge. Graphs of the plots are presented in Appendix A.

One distinct advantage these gauges have, is that once they have been adjusted for the first sample of any given size, it is then a matter of seconds to remove it from and/or attach it to another sample. The weakest point of the gauge are the two springs connecting the brackets and the combined tensile strength for these springs is 129.5 N which is sufficient for most applications. There is no tendency for the bands to stretch below 200 N therefore the gauge assembly is as rigid as the springs.

References

Millette, Daniel G.; *Lateral deformation gauge;* CANMET report MRL 92-010; CANMET, Energy, Mines and Resources Canada; 1992

Annor, A, Millette, D.; *Laboratory studies optimization of aggregate mix compositions for cemented rockfill - Part I - Progress report;* CANMET report 91-115; CANMET, Energy, Mines and Resources Canada; 1991

Appendix A

Uniaxial Compression Test Data

Uniaxial Compression Test Data - Cylinder #1

LOAD kN	*AXIAL DEFORMATION* (mm)	*RADIAL DEFORMATION 1* (mm)	*RADIAL DEFORMATION 2* (mm)	*RADIAL DEFORMATION 3* (mm)
0.0	0.00	0.28	1.30	0.26
0.6	0.15	0.28	1.30	0.26
0.9	0.30	0.28	1.30	0.26
0.8	0.45	0.28	1.30	0.26
0.8	0.60	0.28	1.30	0.26
0.6	0.75	0.28	1.30	0.26
0.6	0.90	0.28	1.30	0.26
0.6	1.05	0.28	1.30	0.26
0.6	1.20	0.28	1.30	0.26
0.5	1.35	0.28	1.30	0.26
0.8	1.50	0.28	1.30	0.26
1.0	1.65	0.28	1.30	0.26
1.0	1.80	0.28	1.30	0.26
1.3	1.95	0.28	1.31	0.26
1.3	2.10	0.28	1.31	0.26
1.4	2.25	0.28	1.31	0.26
1.7	2.40	0.28	1.31	0.26
1.9	2.55	0.28	1.31	0.26
2.4	2.70	0.28	1.31	0.26
3.9	2.85	0.28	1.31	0.26
6.7	3.00	0.28	1.31	0.26
10.7	3.15	0.28	1.31	0.26
16.8	3.30	0.28	1.31	0.26
25.5	3.45	0.28	1.31	0.26
37.2	3.60	0.28	1.31	0.26
56.1	3.75	0.28	1.31	0.26
84.1	3.90	0.28	1.31	0.26
110.8	4.05	0.28	1.31	0.26
131.8	4.20	0.28	1.31	0.26
144.6	4.35	0.28	1.31	0.26
151.8	4.50	0.28	1.31	0.26
155.3	4.65	0.28	1.31	0.26
157.1	4.80	0.28	1.31	0.26
158.2	4.95	0.28	1.31	0.26
161.1	5.10	0.28	1.31	0.26
166.2	5.25	0.28	1.31	0.26
171.4	5.40	0.28	1.31	0.26
198.6	5.55	0.28	1.31	0.26
251.9	5.70	0.28	1.31	0.26
302.2	5.85	0.28	1.31	0.26
355.1	6.00	0.28	1.31	0.26
392.6	6.15	0.28	1.31	0.26
452.7	6.30	0.28	1.31	0.26
518.4	6.45	0.28	1.31	0.26
568.4	6.60	0.28	1.31	0.26
624.2	6.75	0.28	1.31	0.26
671.7	6.90	0.28	1.31	0.26
717.8	7.05	0.28	1.31	0.26
755.9	7.20	0.28	1.31	0.26
788.1	7.35	0.28	1.30	0.26
820.4	7.50	0.28	1.29	0.26
845.8	7.65	0.28	1.29	0.26
867.3	7.80	0.28	1.28	0.26
880.5	7.95	0.28	1.27	0.24
890.4	8.10	0.28	1.26	0.24
895.8	8.25	0.28	1.24	0.23
894.2	8.40	0.28	1.21	0.22
886.0	8.55	0.28	1.16	0.21
878.0	8.70	0.28	1.11	0.20
870.2	8.85	0.28	1.05	0.18
858.6	9.00	0.28	0.99	0.17

TEST CYLINDER 1

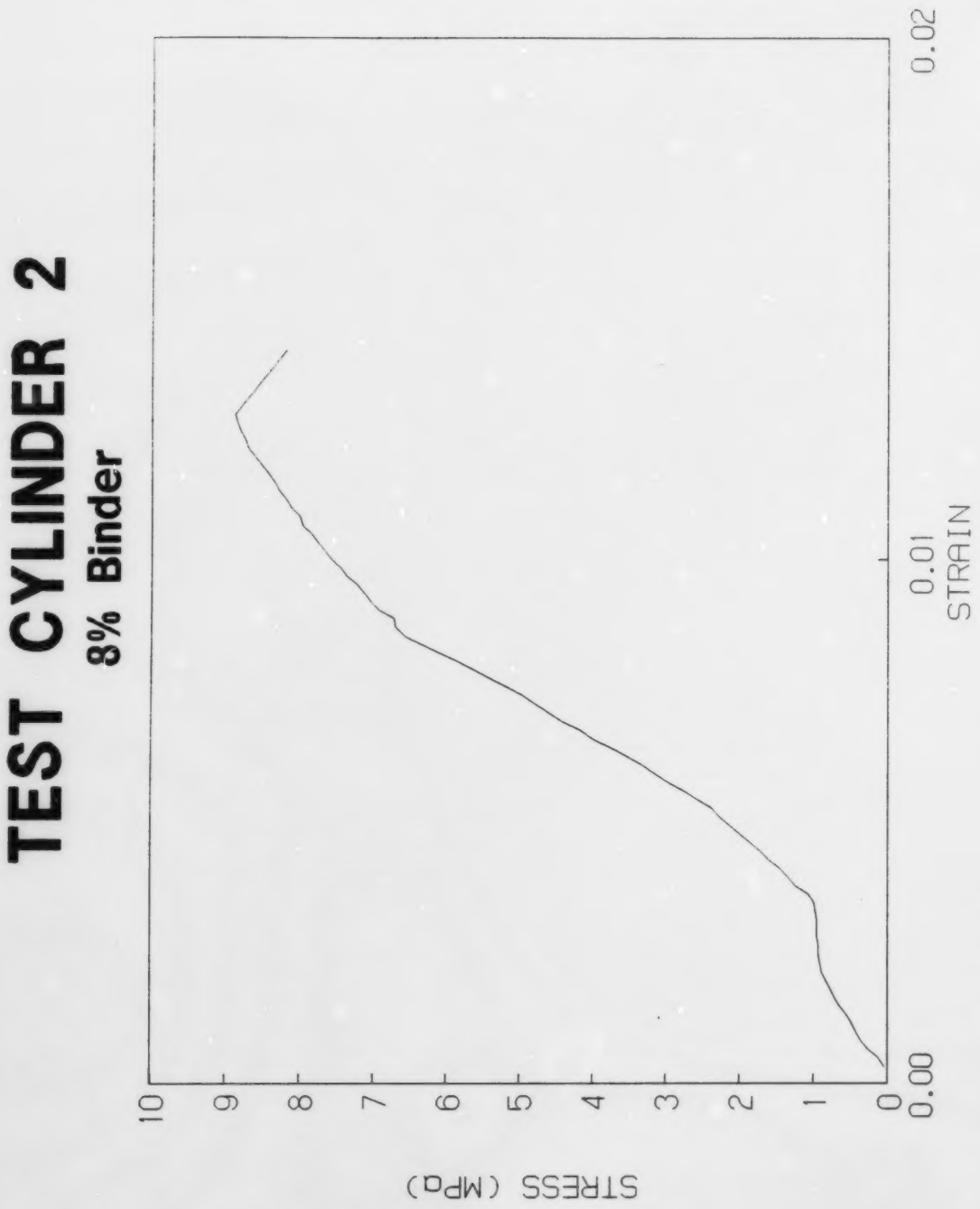
6% Binder

Uniaxial Compression Test Data - Cylinder #2

LOAD kN	*AXIAL DEFORMATION* (mm)	*RADIAL DEFORMATION 1* (mm)	*RADIAL DEFORMATION 2* (mm)	*RADIAL DEFORMATION 3* (mm)
0.0	0.00	0.25	1.16	0.31
0.4	0.15	0.25	1.16	0.31
5.8	0.30	0.25	1.16	0.31
20.8	0.45	0.25	1.16	0.31
42.8	0.60	0.25	1.16	0.31
58.5	0.75	0.25	1.16	0.31
69.7	0.90	0.25	1.16	0.31
80.7	1.05	0.25	1.16	0.31
92.8	1.20	0.25	1.16	0.31
105.8	1.35	0.25	1.16	0.31
117.7	1.50	0.25	1.16	0.31
129.0	1.65	0.25	1.16	0.31
137.7	1.80	0.25	1.16	0.31
144.8	1.95	0.25	1.16	0.31
150.6	2.10	0.25	1.16	0.31
153.3	2.25	0.25	1.16	0.31
155.1	2.40	0.25	1.16	0.31
156.4	2.55	0.25	1.16	0.31
157.6	2.70	0.25	1.16	0.31
158.5	2.85	0.25	1.16	0.31
159.9	3.00	0.25	1.16	0.31
163.9	3.15	0.25	1.16	0.31
177.3	3.30	0.25	1.16	0.31
204.2	3.45	0.25	1.16	0.31
221.7	3.60	0.25	1.16	0.31
240.8	3.75	0.25	1.16	0.31
262.9	3.90	0.25	1.16	0.31
282.9	4.05	0.25	1.16	0.31
306.5	4.20	0.25	1.16	0.31
327.8	4.35	0.25	1.16	0.31
350.7	4.50	0.25	1.16	0.31
372.9	4.65	0.25	1.16	0.31
392.7	4.80	0.25	1.16	0.31
425.3	4.95	0.25	1.16	0.31
452.9	5.10	0.25	1.16	0.31
485.0	5.25	0.25	1.16	0.31
515.1	5.40	0.25	1.16	0.31
547.8	5.55	0.25	1.16	0.31
580.7	5.70	0.25	1.16	0.31
613.3	5.85	0.25	1.16	0.31
653.8	6.00	0.25	1.16	0.31
688.1	6.15	0.25	1.16	0.31
722.4	6.30	0.25	1.16	0.31
752.1	6.45	0.25	1.16	0.31
783.1	6.60	0.25	1.16	0.31
815.2	6.75	0.25	1.16	0.31
847.1	6.90	0.25	1.16	0.31
883.5	7.05	0.25	1.16	0.31
919.5	7.20	0.25	1.16	0.31
961.3	7.35	0.25	1.16	0.31
1001.8	7.50	0.24	1.16	0.31
1041.1	7.65	0.24	1.16	0.31
1079.9	7.80	0.24	1.16	0.31
1098.8	7.95	0.24	1.16	0.31
1118.8	8.10	0.24	1.16	0.31
1138.5	8.25	0.24	1.16	0.31
1156.1	8.40	0.23	1.16	0.31
1169.5	8.55	0.23	1.16	0.31
1189.2	8.70	0.23	1.16	0.31
1209.5	8.85	0.22	1.16	0.31
1225.5	9.00	0.22	1.16	0.31

Uniaxial Compression Test Data - Cylinder #2 (cont'd)

LOAD kN	*AXIAL DEFORMATION* (mm)	*RADIAL DEFORMATION 1* (mm)	*RADIAL DEFORMATION 2* (mm)	*RADIAL DEFORMATION 3* (mm)
1243.8	9.15	0.21	1.16	0.31
1262.9	9.30	0.21	1.16	0.31
1277.3	9.45	0.20	1.16	0.31
1292.4	9.60	0.19	1.16	0.31
1307.4	9.75	0.18	1.16	0.31
1317.2	9.90	0.18	1.16	0.31
1333.2	10.05	0.17	1.16	0.31
1344.3	10.20	0.16	1.16	0.31
1358.8	10.35	0.15	1.16	0.31
1372.2	10.50	0.14	1.16	0.31
1386.1	10.65	0.13	1.16	0.31
1401.9	10.80	0.12	1.16	0.31
1414.4	10.95	0.11	1.16	0.31
1427.7	11.10	0.10	1.16	0.31
1437.3	11.25	0.09	1.15	0.31
1448.4	11.40	0.07	1.15	0.31
1454.3	11.55	0.06	1.15	0.31
1459.7	11.70	0.04	1.15	0.31
1459.6	11.55	0.02	1.14	0.32
1457.6	11.40	0.00	1.13	0.32
1452.7	11.25	- 0.03	1.12	0.33
1427.2	11.10	- 0.05	1.12	0.33
1371.2	10.95	- 0.06	1.11	0.32
1288.2	10.80	- 0.07	1.11	0.32
1041.8	10.65	- 0.07	1.11	0.32
833.4	10.50	- 0.07	1.11	0.32
682.3	10.35	- 0.07	1.11	0.32
545.7	10.20	- 0.07	1.11	0.32
438.7	10.05	- 0.07	1.11	0.32
352.6	9.90	- 0.07	1.11	0.32
291.2	9.75	- 0.06	1.12	0.32
220.1	9.60	- 0.06	1.12	0.32
168.6	9.45	- 0.06	1.12	0.32


TEST CYLINDER 2
8% Binder
STRESS (MPa)
10
9
8
7
6
5
4
3
2
1
0
0.00
0.01
0.02
STRAIN

Uniaxial Compression Test Data - Cylinder #3

LOAD kN	*AXIAL DEFORMATION* (mm)	*RADIAL DEFORMATION 1* (mm)	*RADIAL DEFORMATION 2* (mm)	*RADIAL DEFORMATION 3* (mm)
0.0	0.00	0.55	1.41	0.57
0.2	0.15	0.55	1.41	0.57
4.6	0.30	0.55	1.41	0.57
16.3	0.45	0.55	1.41	0.57
21.5	0.60	0.55	1.41	0.57
28.0	0.75	0.55	1.41	0.57
42.2	0.90	0.55	1.41	0.57
60.7	1.05	0.55	1.41	0.57
83.6	1.20	0.55	1.41	0.57
107.5	1.35	0.55	1.41	0.57
127.0	1.50	0.55	1.41	0.57
140.9	1.65	0.55	1.41	0.57
148.8	1.80	0.55	1.41	0.57
152.7	1.95	0.55	1.41	0.57
154.5	2.10	0.55	1.41	0.57
156.2	2.25	0.55	1.41	0.57
157.4	2.40	0.55	1.41	0.57
159.9	2.55	0.55	1.41	0.57
163.8	2.70	0.55	1.41	0.57
167.5	2.85	0.55	1.41	0.57
215.3	3.00	0.55	1.41	0.57
264.1	3.15	0.55	1.41	0.57
309.6	3.30	0.55	1.41	0.57
350.6	3.45	0.55	1.41	0.57
379.5	3.60	0.55	1.41	0.57
421.3	3.75	0.55	1.41	0.57
467.6	3.90	0.55	1.41	0.57
511.1	4.05	0.55	1.41	0.57
562.0	4.20	0.55	1.41	0.57
608.3	4.35	0.55	1.41	0.57
711.2	4.50	0.55	1.41	0.57
750.4	4.65	0.55	1.41	0.57
793.0	4.80	0.55	1.41	0.57
828.9	4.95	0.55	1.41	0.57
870.8	5.10	0.55	1.41	0.57
905.8	5.25	0.55	1.41	0.57
942.9	5.40	0.55	1.41	0.57
977.8	5.55	0.55	1.41	0.57
1009.6	5.70	0.55	1.41	0.57
1041.2	5.85	0.55	1.41	0.57
1064.7	6.00	0.55	1.41	0.57
1089.0	6.15	0.55	1.41	0.57
1108.9	6.30	0.55	1.41	0.57
1124.7	6.45	0.55	1.41	0.57
1142.9	6.60	0.55	1.41	0.57
1158.2	6.75	0.55	1.41	0.57
1173.3	6.90	0.55	1.41	0.57
1187.0	7.05	0.55	1.41	0.57
1202.2	7.20	0.55	1.41	0.57
1214.2	7.35	0.55	1.41	0.57
1225.2	7.50	0.54	1.41	0.57
1241.9	7.65	0.54	1.41	0.57
1254.8	7.80	0.54	1.41	0.57
1266.2	7.95	0.54	1.41	0.57
1280.5	8.10	0.54	1.41	0.57
1291.8	8.25	0.54	1.41	0.57
1305.2	8.40	0.54	1.41	0.57
1316.7	8.55	0.53	1.41	0.57
1330.2	8.70	0.53	1.41	0.57
1341.1	8.85	0.52	1.41	0.57
1352.5	9.00	0.52	1.41	0.57

Uniaxial Compression Test Data - Cylinder #3 (cont'd)

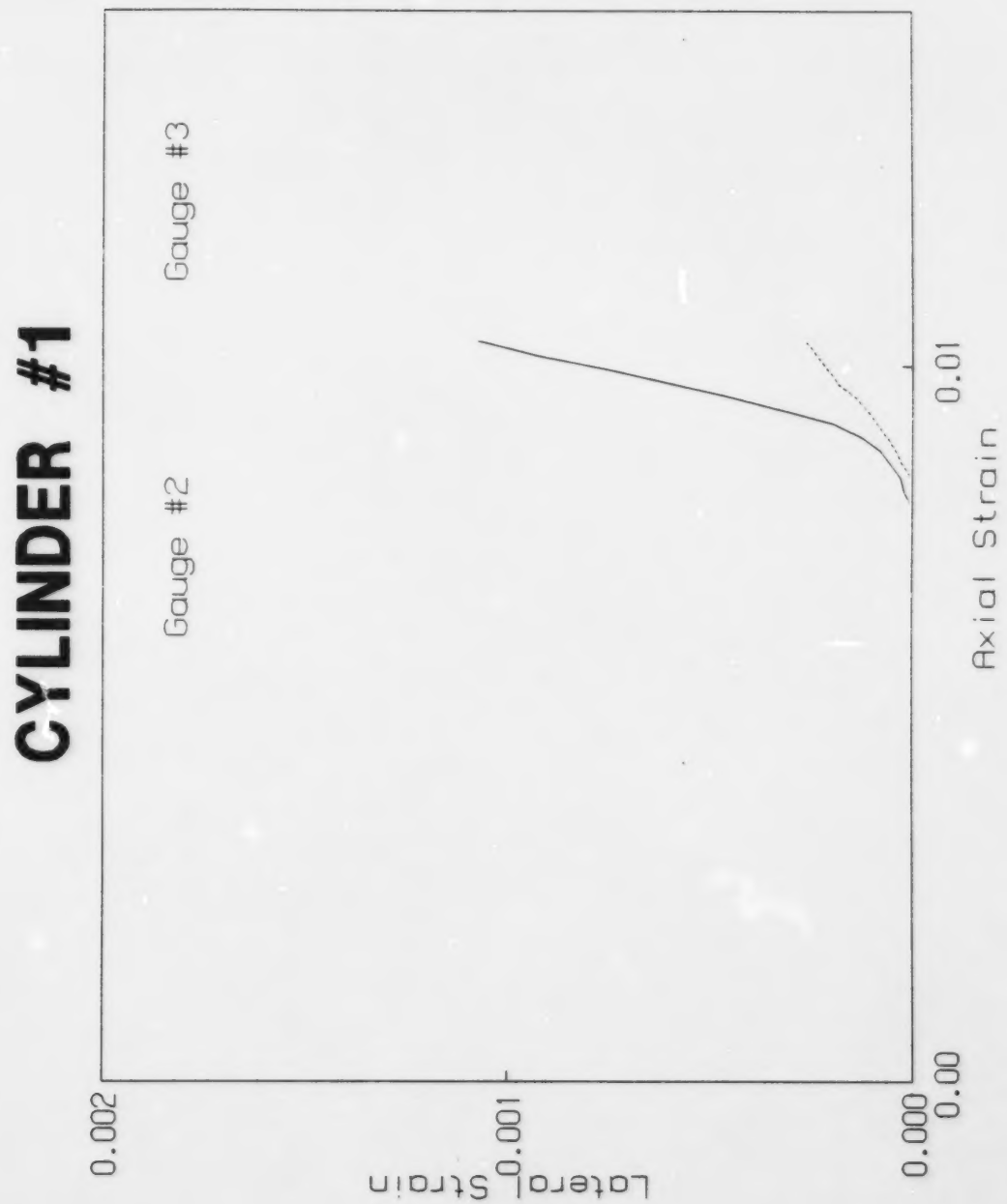
LOAD kN	*AXIAL DEFORMATION* (mm)	*RADIAL DEFORMATION 1* (mm)	*RADIAL DEFORMATION 2* (mm)	*RADIAL DEFORMATION 3* (mm)
1360.3	9.15	0.51	1.41	0.57
1365.7	9.30	0.50	1.41	0.57
1370.7	9.45	0.48	1.41	0.57
1374.6	9.60	0.46	1.41	0.57
1376.2	9.75	0.44	1.41	0.57
1372.9	9.90	0.41	1.41	0.57
1368.0	10.05	0.39	1.41	0.57
1365.3	10.20	0.36	1.41	0.57
1360.8	10.35	0.33	1.41	0.57
1320.4	10.50	0.30	1.41	0.57
1238.6	10.65	0.29	1.41	0.57
1028.4	10.80	0.29	1.41	0.57
812.5	10.65	0.29	1.41	0.57
664.2	10.50	0.29	1.41	0.57
530.3	10.35	0.29	1.41	0.57
427.2	10.20	0.29	1.41	0.57
355.5	10.05	0.29	1.41	0.57
278.6	9.90	0.29	1.41	0.57
208.8	9.75	0.29	1.41	0.57
165.1	9.60	0.29	1.41	0.57
156.0	9.45	0.29	1.41	0.57
147.5	9.30	0.29	1.41	0.57

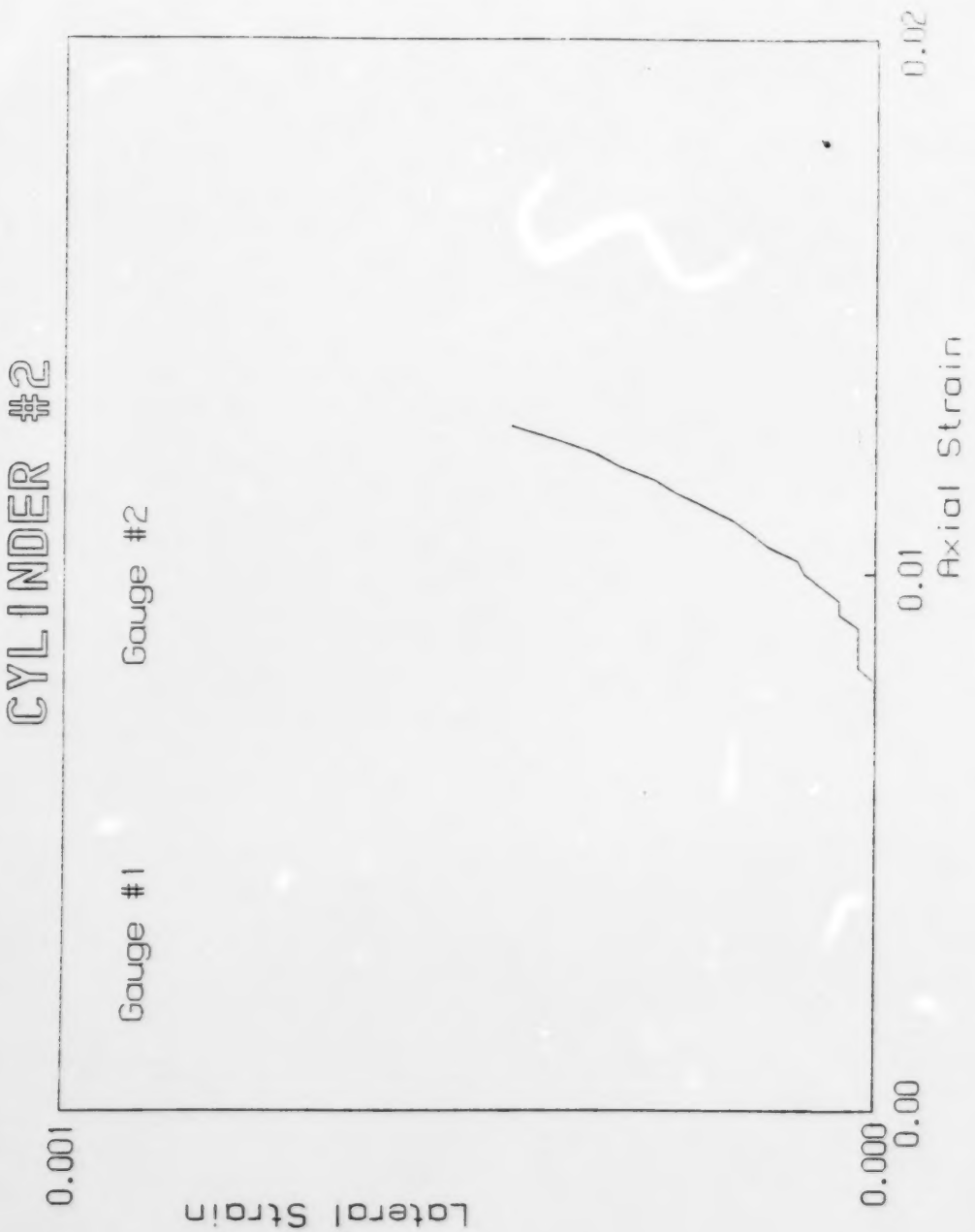
TEST CYLINDER 3

8% Binder

Appendix B

Lateral Strain/Axial Strain Graphs


CYLINDER #1
Gauge #2
Gauge #3
Lateral Strain
0.002
0.001
0.000
0.00
0.01
Axial Strain


CYLINDER #2
Gauge #1
Gauge #2
Lateral Strain
Axial Strain
0.001
0.000
0.00
0.01
0.02

Cylinder #3
Gauge #1
Lateral Strain
0.001
0.000
0.00
0.01
0.02
Axial Strain